

**THE EFFECTIVENESS OF JAWBONE MONITORS IN DECREASING SEDENTARY
BEHAVIOR IN ADULTS**

A THESIS

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Chapter I

Introduction

Background

It is recommended that each adult accumulate 150 minutes per week of moderate-intensity physical activity (PA) or 75 minutes per week of vigorous-intensity PA in bouts of 10 minutes or more (69). One way moderate-intensity PA can be defined is in terms of metabolic equivalents (METs, the metabolic cost of PA relative to resting levels) as any PA with a MET demand between 3.0-5.9 METs, whereas any activity that produces a $\text{MET} \geq 6.0$ would be considered vigorous-intensity. These recommendations were put in place because participation in regular PA has been shown to play a role in the prevention of major chronic diseases such as cardiovascular disease, type II diabetes, obesity, and some types of cancer (6). Despite the overwhelming evidence that regular participation in moderate-intensity to vigorous-intensity PA (MVPA) provides numerous health benefits and a preventative role in chronic disease, PA is not the sole contributor in the reduction of disease and illness.

Sedentary behavior (SB) and the accumulation of SB have been shown to be a health risk independently of PA and exercise participation (26). SB can be defined as any activity with a MET requirement of 1.0-1.5, which typically includes activities such as sitting, lying, driving, watching television, and working on the computer (46). Greer et al. found that men classified with middle (> 12 to < 19 hours/week) and high (> 19 hour/week) SB had 65-76% higher risk of developing metabolic syndrome independently of PA levels compared to individuals who were classified as having low level of SB (26). Additional health risks associated with SB include but are not limited to increased insulin resistance, increased fasting triglycerides, decreased daily caloric

expenditures, and increased incidences of hypertension (43, 44, 53). Moreover, Matthews et al. showed that the amount of time spent in SB was positively associated with mortality after adjusting for covariates, such as age, sex, education, smoking, diet, race, and MVPA (44).

In addition to accumulated SB, the duration of bouts in SB has also been shown to increase health risks in conjunction with total accumulated SB. Therefore, total time spent in SB can be considered alongside bouts of SB, with both posing as a potential health risks to individuals. Cliff et al. found that children who spend longer time in bouts of SB have lower HDL cholesterol than those in shorter duration bouts of SB (14). These findings were consistent with adult studies which indicate that limiting bouts of SB to < 30 minutes have beneficial effects on cardio-metabolic outcomes (57).

Breaks in SB go hand-in-hand with the duration of bouts spent in SB. Increased breaks in SB have also been shown to decrease health risks involved with too much sitting time. Frequent interruptions (breaks) to SB are commonly defined as the transition from sedentary to an active state for ≥ 1 min (30). Breaks in sedentary time have beneficial associations with waist circumference, body mass index, triglyceride levels, and 2-hour glucose levels that are independent of total SB and MVPA time (30). Dunstan et al. found that interrupting sitting time with short bouts of light- or moderate-intensity walking lowers postprandial glucose and insulin levels in overweight/obese adults (20). Furthermore, increasing interrupted SB has been shown to reduce resting blood pressure in overweight/obese adults (38). Current evidence suggests that breaking up SB may provide beneficial metabolic effects in addition to the beneficial effects of reducing total SB and increasing time spent in MVPA.

Population-based studies have shown that more than half of an average person's waking day is spent in SB (17, 43). Coupled with the amount of time the average person spends in SB and the lack of participation in moderate or vigorous PA, there is a need for individuals to increase time spent participating in PA and to decrease time spent in SB.

Currently, consumer-based PA monitor sales are on the rise. In 2014, an estimated 70.2 million consumer-based PA monitors were purchased in the U.S., Europe, and Asia (1). With respect to Jawbone monitors, approximately 500,000 were sold in the United States alone, in 2014 (1). Consumer-based PA monitors are designed to measure and store the amount of PA performed by an individual on a day-to-day basis. They also provide direct feedback to the individual user on the progress to, and completion of, daily PA goals. Additionally, some devices such as the Jawbone monitor have settings that can cause vibrations when the consumer has been sedentary for too long. This vibration from the monitor itself provides a haptic feedback sensation that the individual has been engaged in SB for an extended period of time (e.g., 60 minutes). The use of these PA monitors may directly influence the behaviors of the individual which could translate into decreased SB and increased PA. A meta-analysis completed in 2007 found that the use of pedometers over an 18 week period increased PA in adults by an average of 2491 steps per day (9). These improvements may be related back to the feedback provided by the pedometers. Consumer-based PA monitors, which are similar to their output to pedometers, may have the same potential to promote behavioral change (13, 77).

Theories such as self-determination theory and stimulus-response theory may explain why haptic feedback could potentially influence behavior change, and motivational techniques including goal-setting and prompting may also help elicit behavior change (40). To date, there has been limited research done with regards to if haptic feedback from PA monitors can create actual

behavioral changes. However, there are studies that have shown how haptic feedback and prompting can promote behavioral adaptations (5, 48, 67). Swartz et al. utilized two different prompting techniques to determine if haptic feedback could decrease SB (67). Both intervention groups significantly reduced duration of average sitting bouts (Stand group, by 16%; Step group, by 19%) and the number of sitting bouts of 60 minutes or more (67). Therefore, it may be that similar results can be seen in other devices that offer cues or prompts to cause a behavioral change.

Purpose

Most research on PA monitors focused on the reliability and validity. However, less is known about whether or not these devices can assist in behavioral modification in the individuals using them. Therefore, the purpose of this study was to evaluate the effectiveness of Jawbone monitors in decreasing SB in adults aged 18-85 from Muncie, Indiana.

Aims and Hypotheses

Aim 1: To determine if wearing the Jawbone and receiving haptic feedback is related to differing time spent in SB, bouts of SB, and number of breaks in SB than when the monitor is worn but no haptic feedback is provided.

- **Hypothesis 1a:** The use of the Jawbone monitor with haptic feedback will be related to individuals spending less total time in SB compared to wearing the monitor and not receiving haptic feedback.
- **Hypothesis 1b:** The use of the Jawbone monitor with haptic feedback will be related to individuals spending less time in bouts of SB compared to wearing the monitor and not receiving haptic feedback.

- **Hypothesis 1c:** The use of the Jawbone monitor with haptic feedback will be related to individuals increasing breaks in SB compared to wearing the monitor and not receiving haptic feedback.

Aim 2: To determine if wearing the Jawbone and receiving haptic feedback is related to acquiring differing steps, caloric expenditure, and activity time per day compared to wearing the monitor and not receiving feedback.

- **Hypothesis 2a:** The use of the Jawbone monitor with haptic feedback will be related to individuals acquiring more steps per day compared to wearing the monitor and not receiving haptic feedback.
- **Hypothesis 2b:** The use of the Jawbone monitor with haptic feedback will be related to increased caloric expenditure compared to wearing the monitor and not receiving haptic feedback.
- **Hypothesis 2c:** The use of the Jawbone monitor with haptic feedback will be related to increased activity time per day compared to wearing the monitor and not receiving haptic feedback.

Delimitations

The study could be delimited by the following factors:

1. This study utilized male and female adults from Muncie, Indiana, ages 18-75.
2. The use of the Jawbone UP24 PA monitor was used because of its unique vibrating feature. Other consumer-based PA monitors were not tested in this study.
3. The number of steps, kcals, and active time per day were measured by the Jawbone accelerometers.

4. activPAL accelerometers were used to detect changes in SB and PA as well as generate a criterion measure for steps, breaks in SB, and time spent in SB, standing and stepping.
5. Each participant wore both the Jawbone UP and activPAL monitors for two sessions of 7 days. The only difference between sessions is that for half the participants, haptic feedback from the monitor was provided during the second session when the individual was inactive for a bout of >60 minutes. Individuals did not have access to real-time data from the PA monitor.

Definitions

1. Physical Activity: any bodily movement produced by the contraction of skeletal muscles that result in a substantial increase in caloric requirements over resting energy expenditure (12).
2. Metabolic Equivalent (MET): a term used to represent resting metabolism and is taken, by convention, to be 3.5 ml/kg/min. This is called 1 MET (11).
3. Moderate Intensity PA: an activity with a metabolic demand between 3.0 – 5.9 METs.
4. Vigorous Intensity PA: an activity with a metabolic demand ≥ 6.0 METs.
5. Reliability: the extent to which an experiment, test, or measurement procedure yields the same results on repeated trials.
6. Validity: the quality of being real or correct.

Chapter II

Literature Review

Part 1: Physical Activity

Physical Activity and Health

Physical activity (PA) is known to be a primary modifiable risk factor in the prevention/attenuation of chronic disease such as cardiovascular and metabolic disease in addition to all-cause mortality (29, 33, 58, 81). To date, there have been numerous epidemiological studies that have demonstrated the important role that PA has on health (7, 29, 33, 54, 58, 59, 81). PA has such an influential positive role on chronic disease because of its accumulated effects on cardiovascular and other chronic disease risk factors (29, 59). It is estimated that world population inactivity causes 30% of ischemic heart disease and 27% of Type II diabetes mellitus (1). In addition, PA has been shown to be beneficial in a dose-response relationship, meaning that some PA can produce substantial health benefits, but higher levels of PA can produce these benefits to a higher degree (56). From a public health perspective, physical inactivity is associated with major economic burden on healthcare, which can be recognized in the United States where healthcare costs are staggering. In 2009, the economic costs of CVD and stroke were estimated at \$475.3 billion and in 2007, medical costs attributed to diabetes was estimated at \$86 billion (39). For the reasons stated above, the American College of Sports Medicine (ACSM), World Health Organization (WHO), and the Centers for Disease Control (CDC) have published recommendations outlining the importance of PA, the minimum level of PA for health related benefits, and strategies to achieve these levels of PA.

PA Guidelines

In an effort to communicate the health benefits of regular PA and risks of physical inactivity, the first United States government-sanctioned guidelines for PA, the 2008 Physical Activity Guidelines for Americans (PAG) were established (63). These guidelines recommend that all Americans should participate in a minimum of 150 minutes per week of moderate intensity aerobic PA, or 75 minutes per week of vigorous intensity aerobic PA, or a combination of both which can be obtained in bouts of 10 minutes or more (63). Moderate and vigorous intensity PA are often defined in terms of energy expenditure (EE), percent of age-predicted heart rate maximum, and rating of perceived exertion (RPE), as described in the next section. While these guidelines outlines the minimum threshold of PA necessary to gain health benefits, the PAG also specifies that PA exceeding this is likely to lead to obtaining additional health benefits.

The prevalence of American adults meeting the recommended level of aerobic PA in the U.S. is low, estimated to be between 3% and 52% depending on the method of PA assessment used (62). Considering the potential benefits that PA can have on the individual and the general population, it is important for individuals, practitioners, and researchers to understand how to interpret and apply PA guidelines. This is especially true in the assessment of PA data, specifically, how to quantify PA and how to rate the value of PA.

Quantity and Quality of PA

As stated in the previous section, the PAG prescribes a minimum volume of PA to attain health benefits, which intrinsically contains parameters of frequency, duration, and intensity. For example, the 2008 PAG recommends attaining 150 minutes of moderate intensity PA weekly, ideally during sessions spread across most days of the week (76). Quantity (i.e., 150 minutes) is

relatively easy to calculate from frequency and duration (i.e. 30 minutes, 5 days/week). Quality, or the intensity of PA, can be more much difficult to assess.

Intensity of PA is often broken down into three separate categories; light, moderate, and vigorous intensity. There are several ways to estimate intensity relative to heart rate, oxygen consumption (VO₂), maximal exercise capacity, and RPE (25). Absolute exercise intensity is often gauged by EE, which can be expressed through caloric expenditure or METs (69). Typically, moderate PA corresponds to an oxygen demand of 3.0-5.9 METs and vigorous PA corresponds to an oxygen demand of ≥ 6.0 METs (25). “Active time”, or moderate-to-vigorous intensity PA (MVPA), is a frequently tracked PA variable, which is time accumulated at an intensity of ≥ 3.0 METs (at or above moderate intensity PA). Similar to the PAG, the ACSM recommends 30 minutes daily of MVPA on most days of the week with a total caloric expenditure of $> 1000\text{kcal}/\text{week}$ or volume of 500-1000 MET-min/week (25).

An indirect way to gauge quantity of PA is through knowing how many steps an individual takes per day. Tudor Locke et al. developed the most common way to classify overall PA: sedentary <5000 steps/day; low active 5000-7499 steps/day; somewhat active 7500-9999 steps/day; active ≥ 10000 -12499 steps/day; and very active ≥ 12500 steps/day (74). Together, steps, EE, and active time are practical methods of comparing PA levels to the PA guidelines.

Part 2: Sedentary Behavior

Sedentary Behavior and Health

While the health benefits of PA are fairly well-established, the health risks of SB are becoming more recognized and understood (19, 21, 27, 28, 31, 35, 65). Since 2005, there has been an increase in research demonstrating the health hazards of prolonged time spent in SB (e.g.,

sitting, watching television, using a computer, desk work, etc.) (69). Recent epidemiologic evidence suggests that the metabolic and long-term health consequences of habitual SB (too much sitting) are distinct from those associated with a lack of PA (too little exercise) (19, 28, 31, 35, 65). That is, SB can be associated with health risks such as increased insulin resistance, increased fasting triglycerides, increased incidences of hypertension, decreased EE, and excess weight gain, independent of PA levels. SB can be defined on an acute level with total accumulated SB on a daily basis (hours), in bouts of SB, and breaks in SB (30, 31, 50). SB can also be defined as any activity with a MET requirement of 1.0-1.5, which typically included the activities listed above (26). While it is common to hear individuals not meeting PA guidelines described as “sedentary”, this should not be confused with SB. SB lies on a spectrum of activity intensities, with SB being the lowest (1.0-1.5 METs) intensity and MVPA being at the other end of the intensity spectrum (≥ 3.0 METs). Between SB and MVPA is light-intensity PA, which has an EE of 1.6-2.9 METs. It is possible to have high amounts of SB and high MVPA if time in light-intensity PA is low; Owen et al. call individuals with high SB and high MVPA “active couch potatoes” (52).

Data suggests that individuals who have high SB have a 30% higher risk of all-cause mortality compared to those with low SB (8). Matthews et al. recently reported that American adults spend an average of 55% of their waking day in SB. Additionally, objective data from the Matthews et al. study suggests that 1 in 4 white American adults spend > 70% of their waking hours sitting (43).

Greer et al. found that men classified with middle and high SB had 65-76% higher risk of developing metabolic syndrome independently of MVPA levels compared to individuals who were classified as having a low level of SB (26). Additional health risks associated with SB include but are not limited to increased insulin resistance, increased fasting triglycerides, decreased daily

caloric expenditures, and increased incidences of hypertension (53). Moreover, Matthews et al. showed that the amount of time spent in SB was positively correlated with mortality after adjusting for variables, such as age, weight, BMI, and gender (43, 44).

Although PA and exercise can reduce the negative side effects of SB, as Katzmarzyk et al. illustrated, active individuals who spend significant amounts of time in SB outside of PA still have increased risk for mortality and the development of cardiovascular and metabolic risk factors (35). Therefore, it has been suggested that new PA guidelines be established to promote PA, but also reduce time spent in SB (28).

Accumulation of SB

Recent evidence indicates that total time spent in SB is associated with health. Owen et al. divided SB into four quartiles, the first representing ≤ 6 hours of SB (associated with the lowest health risk), whereas the fourth quartile representing ≥ 10.2 hours of SB (associated with the highest health risk). Furthermore, the second and third quartile, 7.7 hours and 8.8 hours, respectively have greater health risks compared to the lowest quartile of ≤ 6 hours of SB (53). Greer et al. found that men classified with middle (>12 to ≤ 19 hours/week) and high (> 19 hours/week) SB had 65-76% higher risk of developing metabolic syndrome independently of PA levels compared to individuals who were classified as having low level (≤ 12 hours/week) of SB (26). The Greer et al. study did include sleep time with the above classification groups. Additional studies have verified the same findings as Owen and Greer that the more time spent in SB throughout the day leads to significantly higher risk of developing cardiovascular and metabolic risk factors/diseases (21, 24, 31, 57, 70). Furthermore, several studies have shown a dose-response relationship such that greater amounts of total time spent sitting resulted in increased risk of disease. For instance, a large cohort of women demonstrated that, for each 2-hour/day increase in

time spent watching television, there was a 23% increase in risk for obesity and a 14% increase in the risk for T2DM (32).

Bouts of SB

It has been shown that not only does accumulated SB time throughout the day increase health risk, but also the number and duration of bouts of SB (4, 30). Cliff et al. studied the patterns of SB in adolescent children. They found that those children who participated in SB bouts ≥ 30 - minutes had lower HDL cholesterol than those who participated in SB bouts < 10 minutes (14). These findings were consistent with adult studies which indicate that limiting bouts of SB to < 30 minutes have beneficial effects on cardio-metabolic outcomes (57). Furthermore, Owen et al. recommended a 5-minute break every hour, and Ryan et al. suggested that office workers can achieve this goal (51, 61). Thomas et al. tested 3 conditions presented in a randomized counterbalanced order involving smartphone-based prompts for walking breaks of (a) 3 min after 30 SB minutes, (b) 6 minutes after 60 SB minutes, and (c) 12 minutes after 120 SB minutes. The 3- and 6-minute conditions resulted in more walking breaks, the best adherence to prompts, the greatest amount of daily time spent in walking breaks, and fastest adherence to prompts ($P < .01$) (68). This suggests that individuals whom receive prompts to promote behavioral change are more likely to adhere to the behavioral change shorter bouts of MVPA after 30-60 minute bouts of SB compared to longer bouts of MVPA after longer bouts of SB. Overall, the individuals who are chronically participating in SB of bouts of ≥ 60 min is particularly alarming because our current daily habits and activities are conducive to prolonged SB, rather than short bouts, contributing more so to the overall total time being sedentary.

Breaks in SB

Increased breaks in SB have been shown to decrease health risks involved with too much sitting time. Frequent interruptions (breaks) to SB are commonly defined as the transition from sedentary to an active state for ≥ 1 min (30). Breaks in sedentary time have beneficial associations with waist circumference, body mass index, triglyceride levels, and two-hour glucose levels that are independent of total SB and MVPA time (30). Dunstan et al. found that interrupting sitting time with short bouts of light- or moderate-intensity walking lowers postprandial glucose and insulin levels in overweight/obese adults (20). Furthermore, increasing interrupted SB has been shown to reduce resting blood pressure in overweight/obese adults (38). One possible positive outcome of increased breaks in SB occurs because of the added EE obtained from reducing prolonged bouts of SB without interruption. Even activities such as standing to interrupt SB has been shown to increase overall daily EE compared to sitting (30). Current evidence suggests that breaking up SB may provide beneficial metabolic effects in addition to the beneficial effects of reducing total SB and potentially increasing time spent in MVPA.

Part 3: PA and SB Assessment

There are numerous PA recommendations that have been broken down into specific volumes, intensities, and times. Therefore, researchers and individuals in the general population need methods of assessing these components of PA and SB. Many types of PA assessment methods are available for field-based research, ranging from subjective methods (e.g., questionnaires) to objective methods (e.g., monitoring devices). Currently, there is no true “gold standard” for assessing PA or SB in field-based settings; however there are several methods that have varying validity, feasibility, and cost in personal use and research grade assessments.

Subjective Methods

Subjective assessments of PA and SB include questionnaires, diaries, logs, and interviews. Historically, PA has been assessed through subjective questionnaires. Epidemiological research interested in PA, SB, and health was based on self-reported data (33, 37, 54). A unique advantage of questionnaires is their ability to be easily administered to large samples due to low cost and low participant burden. An example of a PA questionnaire study was the Harvard Alumni study which resulted in large samples to analyze PA relationships to health outcomes (i.e., all-cause mortality) (54, 55). However, though questionnaires are inexpensive and easily administered to large cohorts, these subjective assessments are often limited by poor memory and recall bias (80). For example, PA levels in the U.S. assessed by questionnaires estimate that 50% of people meet PA guidelines (CDC). However, these estimates are found to be much lower (<5%) when assessed using objective methods, which eliminates recall bias and issues with memory (71).

Objective Methods

Objective methods, such as PA monitors, indirect calorimetry, and doubly-labeled water, avoid the disadvantages of subjective PA measurements. While indirect calorimetry and doubly-labeled water are extremely accurate for the measurement of EE, they are unable to collect information about PA patterns and types, and, are expensive to administer; additionally, indirect calorimetry is not feasible for tracking EE outside of research settings (80). PA monitors, including pedometers, accelerometers, and consumer-based PA monitors offer the ability to objectively track PA and SB variables more easily than the above-mentioned methods (80). The section below describes key characteristics, advantages, and limitations of pedometers, accelerometers, and consumer-based PA monitors.

Pedometers

Mechanical pedometers are objective PA monitors which have been around since the 1960's, although the idea of counting steps is much older. Early pedometers were prone to large measurement error, with technology advancement, they have become popular instruments used for studying and tracking PA (73). Pedometers are small, electronic, and unobtrusive devices that are worn on the waist. The waist location is important due to ambulatory movement translating thought movement of the hip; this allows quantification of the movement, or steps. In this way, pedometers are easy to understand and interpret, and their real-time feedback can be useful for promoting behavior change (73).

Pedometers are a commonly used PA monitor for promoting PA behavioral change. However, pedometers do have notable limitations. Pedometers are mainly limited in that they only pick up ambulatory motions. Also, they can only provide an accumulated total of steps taken, meaning that they can only detect total volume of daily walking PA. They are less accurate for measuring other forms of PA, such as cycling, rowing, or household activities (75). Pedometers are also limited in that they cannot determine the intensity of steps taken or the frequency or duration of PA bouts (73). Additionally, pedometers do not measure accumulated SB, bouts of SB, nor breaks in SB. Despite these limitations, pedometers remain a popular and effective tool for PA assessment and PA intervention.

Accelerometers

Accelerometers are one of the most-commonly used methods for assessing PA and SB in PA and SB research (80). These devices are similar to pedometers in that they are small and are worn attached to a specific site on the body. Accelerometers measure raw acceleration and

deceleration of the body segment to which they are attached to. In general, accelerometers provide valid and objective information regarding PA and SB levels (80). Additionally, accelerometers offer a greater amount of information than pedometers. Accelerometers can track PA variables over long periods of time, in some cases up to a month due to their ability to store data long-term (80). Although these data require special expertise to evaluate, accelerometers can provide valuable information regarding step counts, EE, active time, SB, bouts in SB, and breaks in SB.

The activPAL accelerometer, which was utilized in this study, provides information regarding standing time, stepping time, number of steps per day, sitting time, breaks in SB, and bouts of SB. The activPAL step count function demonstrated very high concurrent validity ($r=0.96$, $p<0.01$) with the ActiGraph step count function. Levels of agreement for sitting, standing, and stepping between direct observation and the activPAL were 100%, 98.1%, 99.2% (18). Furthermore, Aminian et al. found that there were high correlations between the activPAL and video observations in the total number of sit-to-stand transitions ($r=0.99$) and between step counts and direct observation (0.88) (2). Due to its high validity for PA assessment, the activPAL accelerometer served as the criterion measure of PA and SB in this study.

Consumer-Based PA Monitors

Although accelerometers are highly utilized in field-based research, their technical specifications and cost have kept them from gaining popularity in the general public. Over the last several years, a new type of PA monitor, the consumer-based PA monitors, has emerged within the consumer sector. Consumer-based PA monitors are gaining popularity in the general public with their ability to estimate PA variables that the consumer can understand (i.e. steps, active minutes, and kcals) and with the new and improving technology associated with the monitors. Additionally, there are several brands, accessories, and models that are out on the market that offer

unique settings such as the Jawbone UP24 which can vibrate when the user has been sedentary for a pre-determined amount of time. Besides the Jawbone models, there are Fitbits, Garmins, Polar monitors, Apple Watches, and many more. Furthermore, each brand, such as the Jawbone, have several different models (i.e. UP24, UPmove, and UP4).

Consumer-based PA monitors offer numerous advantages over research-grade accelerometers making them desirable for personal PA tracking. For example, most consumer-based PA cost approximately \$75-150 per unit, whereas research-grade accelerometers cost approximately \$200-600 per unit. Additionally, consumer-based PA monitors utilize user-friendly applications to easily display steps, active minutes, caloric expenditure, and goal progression, which eliminates the need for complicated software for analysis or interpretation. One of the most appealing aspects of these monitors is that they provide real-time feedback. They do this by instantly updating the above parameters via screens on a smartphone or monitor display. Similar to pedometers, users can use consumer-based PA monitors to track acute events, such as an exercise bout, or track daily progression towards goals, such as reaching the recommended 10,000 steps per day.

Another appealing and valuable aspect of consumer-based PA monitors that is utilized in the current study, is the real-time feedback aspect of the monitor to “alert” the user to certain PA variables. For instance, the Fitbit Flex has five light indicators (each corresponding to 2,000 steps) that light up as the user takes steps throughout the day to encourage the users to accumulate 10,000 steps. For the current study, we are interested in the Jawbone UP24 alert applications that vibrates to alert the user that they have been sedentary for a predetermined period of time (e.g., 60 minutes), which may encourage the user to get up and move around to break up their prolonged SB. Furthermore, several consumer-based PA monitors track additional appealing variables such as

quantity and quality of sleep, dietary logging, water consumption, and track weight loss. All of these features make consumer-based PA monitors novel and desirable devices to increase PA and SB awareness for the consumer.

PA Monitor Market

In 2013, “wearable fitness technology” sales were estimated at \$330 million worldwide, with 72% (\$238 million) of sales coming from “personal fitness trackers” (47). Furthermore, Generator Research estimates that by 2018, that “wearable fitness technology” sales will reach \$101.2 billion (36). From January 2013 to January 2014, the Fitbit, Jawbone, and Nike brands accounted for approximately 97% of the sales in the U.S., with only 3% of the market being other brands (16). These numbers indicate that a large portion of the U.S. does, and will continue to be utilizing personal tracking technology.

With increasing awareness of the benefits of PA, individuals are noting the value of tracking not only exercise, but daily steps, active minutes, EE, and SB through activities of daily living. In 2013, Consumer Electronic Agency (CEA) conducted an internet survey of 1,006 individuals and 41 one-on-one interviews of online consumers. The CEA reported that the most frequent cited reasons for owning a personal PA monitor was for motivation (52%), monitoring of fitness-related goals and progress towards those goals (47%) and monitoring of PA level or intensity (46%) (47). The same survey reports that 63% of individuals who use wearable PA monitors classify themselves as in excellent or good physical condition; 50% of responders reported meeting the moderate, and 40% reported meeting the vigorous American Heart Association PA guidelines, respectively (47). This suggests that those who could benefit the most from increased PA, PA and SB intervention, and decreased SB may be less likely to be using these devices. The wide-spread use of consumer-based PA monitors and the integration of their

technology into future devices suggest that these monitors could have a significant impact on PA and SB prevalence and health.

Part 4: Consumer-Based PA Monitors and Behavior Change

Because PA monitors provide real-time feedback regarding PA variables, they can be used to objectively compare PA levels to common PA guidelines throughout the day, as well as track SB habits (30). Consumer-based PA monitors are unique in that the user can set specific and individual goals: steps per day, EE, active time, and SB to help meet PA guidelines and to reduce total SB (34, 74). In 2014, Lyons et.al examined 13 electronic personal PA monitors and their associated software application, including the Fitbit Force and Jawbone UP24, regarding their ability for PA behavior change (41). All monitors examined provided self-monitoring, feedback mechanisms, goal-setting and comparisons between current and goal behavior as major behavior change techniques. Some monitors were also able to help the user develop action plans, used past successes to potentially increase self-efficacy, and provided SB reminders. Lyons et al. described that these capabilities of consumer-based PA monitors closely integrate with recommendations from the social cognitive theory and may be effectively used in public health and rehabilitation environments.

Goal Setting

Goal setting is an effective strategy for improving PA and reducing SB (10, 64). Goal setting provides direction, determines the level of effort to be expended, fosters persistence, and supports the search for strategies. Goals should be challenging but realistic in order to promote confidence and maintain motivation pertaining to accomplishing the task. Psychologists have studied goal setting as a motivational technique looking at whether specific, difficult goals

improves performances more than setting no goals. Researchers have also examined the relationship between various types of goals (i.e. specific or general, long-term or short-term, difficult or easy) and PA with results indicating that goals both short and long-term were indeed associated with behavior changes (79). Overall, goal setting has been shown to be an excellent motivational tool to help positivity change PA behavior which can help inactive individuals adhere to long-term PA and reduction of SB. Therefore, individuals who utilize consumer-based PA monitors (i.e. Jawbone UP24) as a goal setting device to reduce SB via the vibration mechanism, are theoretically more likely to accomplish their goals with the help of the monitor and goal setting strategies.

Self-Determination Theory

The self-determination theory (SDT) was originally designed to better explain effective, cognitive, and behavioral responses within an achievement environment (i.e. academics) and is currently applied and utilized in the field of exercise psychology to better explain exercise adherence. The SDT assumes that individuals possess three primary psychological needs: 1) a need for self-determination or autonomy, 2) a need to demonstrate competence, and 3) a need for relatedness (40). Thus, individuals seek challenges that serve to satisfy one or more of these needs. The SDT also includes a conceptual continuum from extrinsic motivation to intrinsic motivation (40). To that end, external regulation refers to the least autonomous type of external motivation while identified regulation refers to the most autonomous type of external motivation prior to one progressing to intrinsic motivation. According to Ryan et al., the SDT has been associated with positive behavioral changes such as smoking cessation and dietary regulation and could be applied to behavioral changes in regards to PA and SB (60). Therefore, the SDT can be applied to the use of monitors providing stimuli (i.e. vibrations) to the user in which the individual performs certain

behaviors (i.e. SB \geq 60 min) and feels competent and autonomous as, and related to, others in the meanwhile.

Stimulus – Response Theory

The Stimulus-Response Theory (SRT) suggests an explanation of how people learn new behaviors. Although a behavior can be learned through repeated pairings of that behavior with antecedent cues or consequent reinforcers, consequences have a greater impact on behavior than do antecedent cues (40). The SRT identifies events that can follow a behavior and the effects these events will have on future behavior. According to the SRT, four types of events – positive reinforcement, negative reinforcement, punishment, and extinction – can follow a behavior and will alter the likelihood of that behavior occurring again in the future (40). The primary focus of the SRT in regards to behavior changes via the Jawbone UP24 monitors occurs around positive reinforcement and punishment response theories.

A positive reinforcement is an enjoyable or pleasant outcome that makes an individual feel good and that strengthens a particular behavior. Within the context of PA, a positive reinforcement is any intrinsic or extrinsic reward that increases the likelihood of an individual participating in PA in the future. Intrinsic reinforcers are rewards that come from within the self, such as feeling good about one's body or feeling a sense of accomplishment at the end of a bout of PA. Extrinsic reinforcements are rewards that come from other people, such as a verbal praise from a fitness instructor. According to the principles of SRT, when individuals receive positive reinforcement after PA, they will be more likely to participate in PA again in the future (40). According to Maki et al., positive reinforcement has been associated with increased exercise participation in individuals with acquired brain injury with non-degenerative damage to brain tissue (42). Positive reinforcement can also be applied to the reduction of SB. For example, an individual who stands

up and walks around for 2-5 minutes after receiving the vibration stimulus from the Jawbone UP24, may feel better about themselves participating in more PA and less SB. Therefore, the concept of positive reinforcement may be a plausible consideration when applied to behavior changes regarding consumer-based PA monitors.

Punishment usually involves an unpleasant or uncomfortable stimulus after a behavior in order to decrease the probability of that behavior happening in the future (40). Individuals generally think of pain as being utilized as punishment, which is not always the case. For example, some women report that they don't want to exercise because they don't like the feeling of being sweaty. For these women, sweat is the punishment - an uncomfortable consequence of exercise that actually deters them from being physically active (40). Therefore, the vibration stimulus from the Jawbone UP24 monitor after SB could be considered a punishment for being inactive (≥ 60 min) similar to Miller and Kraeling finding that electrical stimuli (i.e. punishment) was an effective stimulus for rats to avoid being shocked while trying to gain access to food (45). Consequently, the way punishment is effective with rats may also be effective with humans. Indeed, the vibration from a PA monitor that are associated with SB may help decrease SB from a SRT standpoint and this is important to consider.

Prompts and Behavioral Change

To date, there been little research done regarding to how well the haptic feedback from the PA monitors is at creating behavioral changes. However, there are studies that have shown how haptic feedback and prompting from other types of devices can promote behavioral adaptations (5, 48, 67). A meta-analysis completed in 2015 by Bellicha et al. found that the use of simple prompts such as signs can cause behavioral modifications (5). In worksites (25 studies) and public settings (35 studies), an increase in stair climbing was found during the intervention period, using prompts,

in 64% and 76% of studies, respectively (5). Furthermore, Swartz et al. utilized two different prompting techniques to determine if haptic feedback could decrease SB (67). The first prompt was in the form of an audible “beep” from a wrist-worn monitor that provided the feedback every hour. The second prompt utilized was an audible pop-up message on the computer screen every 60 minutes which said “Hello, please get out of your chair”. Each intervention group received both the wrist-worn feedback and the computer pop-up messages. However, the first intervention group was not given any directions on what to do when they received the feedback and the second intervention group was asked to walk 100 steps each time feedback was given. Both groups significantly reduced duration of average sitting bouts (Stand group, by 16%; Step group, by 19%) and the number of sitting bouts of 60 minutes or more (67). Therefore, one can argue that devices that offer cues or prompts may cause a behavioral change.

Summary of Current Research

In summary, there are numerous studies that show that total accumulated SB, bouts of SB, and breaks in SB are associated with cardiovascular and metabolic risk factors, as well as mortality rates. Currently, there are several consumer-based PA monitors, smartphones, and mobile applications on the market with unique haptic feedback characteristics that may be targeted to reduce SB. Despite the large market for consumer-based PA monitors and the promising tracking utilities and haptic feedback that they provide, there is very limited research examining the effectiveness of these devices in causing behavioral change.

CHAPTER III

Methodology

Participants

Participants for this study included 26 individuals who were either 1) members of Ball State University's Adult Physical Fitness Program (APFP) 2) employees at Ball State University or 3) students at Ball State University in Muncie, Indiana. Individuals 18-75 years of age were eligible to participate in this study. Individuals with an acute illness, any limiting orthopedic issues, or pregnant women were excluded for safety. Prior to participation, potential participants gave written informed consent form which was approved by Ball State University's Institutional Review Board.

Equipment

This study utilized the Jawbone UP24 activity monitor as well as the activPAL (AP) accelerometer to collect data on SB, breaks in SB, time standing and stepping, total steps taken, kilocalories (kcal), and active minutes per day. The Jawbone UP24 monitor was used because of its unique vibrating feature that was set to occur when the individual had been engaged in SB for a certain amount of time. The UP24 can be set to vibrate when sedentary starting as low as 15 minutes and continuing on from there in bouts of 15 minute increments up to 120 minutes. In this study, the vibration setting was set to activate when the user had been sedentary for 60 minutes due to the health risks associated with prolonged SB. Additional measurements from the Jawbone monitor include steps per day, Calories (kcal), and active minutes. The AP accelerometer (criterion measure) was used to track and compare SB, time spent standing and stepping, step counts, and breaks in SB to the Jawbone UP24 monitor. A digital weight scale and stadiometer

was used in the Human Performance Laboratory (HPL) at Ball State University to collect height and weight measurements on each participant during the first visit.

The AP accelerometer was utilized as the criterion method to track PA and SB. Dowd et al. found that the AP was 99.1% accurate when measuring sitting, standing, and slow walking compared to direct observation (18). The AP accelerometer was taped onto the participant's skin of the midline on the anterior aspect of the right thigh for the duration of the intervention (using hypoallergenic Tegaderm adhesive). It should be noted that the AP accelerometer was not part of the intervention of this study, but was utilized to track any changes in SB and PA that occurred from the intervention (Jawbone UP24 monitor with haptic feedback).

Procedures

All participants reported to the HPL for four separate visits. The initial visit to the lab started with an explanation of the study and signing of the informed consent. Next, the researcher collected anthropometric characteristics of each participant which included height, weight, date of birth, and handedness. Additionally, each participant was educated on the characteristics and settings of the Jawbone UP24 monitor. Given that the monitor can be placed into sleep mode by holding a certain button. There was a brief discussion on how and when to activate the sleep mode, since the involuntary activation of sleep mode could reduce the quality of data collected. Also, there was a brief discussion on the vibration aspect of the monitor. Each participant was provided with an explanation on why the Jawbone UP24 may vibrate after a given period of time (i.e. if you are sedentary/inactive for ≥ 60 min there may be a vibration of the device). Participants were encouraged to stand up and move for a brief period of time (e.g. 1-2 minutes) if they felt a vibration from the Jawbone. No further information was disclosed on the health aspects associated with SB.

Following the participant education/discussion portion the participants were informed about the daily tracking involved with the use of a PA monitor. Each participant was asked to record the day the monitor is worn, when the monitor was put on and taken off, and any exercise the participant participated in on a PA log sheet provided by the research staff.

Participant height, weight, age, and idle alert specifications were then entered by the research staff into the Jawbone UP24 application (on an iPod device). Idle alert specifications included time until vibration occurs in respect to SB (60 minutes) and automatic deactivation of vibration features from 10:00 PM until 8:00 AM so that vibration setting did not interfere with normal sleeping habits. Finally, each participant received an AP accelerometer and Jawbone UP24 monitor, which was placed on the participant by the researcher. AP placement was discussed earlier (middle portion of the anterior surface of the thigh) and the Jawbone Up monitor was placed on the participant's non-dominant wrist.

For the initial visit, the vibration characteristic on the Jawbone monitors were disengaged for every participant, and the week of data collection was considered the control condition. Each participant wore the monitors for 8 days, 6 of which were for the entire 24 hours. Trost et al. found that for adults, between 3 and 5 days of monitoring is required to reliably estimate the outcome variables reported in accelerometer studies (72, 78). Furthermore, Ward et al. found that what constitutes as a "day" can be defined as wearing the monitor for 600 minutes during a 24 hour period (78). Participants were instructed to remove monitors for activities such as showering, swimming, and water aerobics and record any time the monitor was not worn on the PA log. The PA log was used to determine compliance with wearing the PA monitors.

The initial visit to HPL took place beginning on a Monday between 11:00 AM and 6:00 PM. The visit took approximately 30 minutes. However, 60-minute block times were scheduled to

account for any additional questions or unforeseen issues. The second visit to the HPL occurred on the Monday morning (7:00 to 11:00 AM) following the first visit. Participants returned their monitors at the second visit, the research staff collected the previous week of data and recharged the monitors so that the participants could come in for their third visit later the same day so that the PA monitors could be placed back on the participant for an additional week of wear time. Each participant was fitted with the same monitors, and the Jawbone vibration feature was activated on half of the participants, whom were randomly assigned (intervention condition). The participants were not informed about what has been changed nor why. The second week of wearing the monitors took place from Monday afternoon (third visit), until the following Monday morning (fourth and final visit), 7:00-11:00 AM. This encompassed 6 additional full days of wear time for the second and final week of the intervention. Total wear time for the monitors included 12 full days and 4 partial days.

For the fourth and final visit, the participant returned the Jawbone UP24 monitor, the AP-accelerometer, and the PA log sheet. The participant then had an opportunity to ask any follow-up questions regarding the study. Additionally, contact information was verified so that the results of the study can be released to each participant if they so choose.

Visit Outline Summary

Visit 1:

Participants reported to the HPL at a prearranged time between 11-6 PM on Monday afternoon. Each participant was given a Jawbone UP24, AP monitor, and PA log with directions on how and when to wear each monitor and how to complete the PA log.

Visit 2:

Participants reported to the HPL at a prearranged time between 7-11 AM on the following Monday morning. Then each participant returned the monitors and PA log for several hours while the research staff collected data and recharged each device.

Visit 3:

Participants reported to the HPL at a prearranged time between 11-6 PM on the same Monday as Visit 2. They were given both monitors again and a PA log, and the Jawbone vibration setting was activated for half of the participants which was randomly assigned.

Visit 4 (final visit):

Participants reported to the HPL at a prearranged time between 7-11 AM the Monday morning following Visits 2 and 3. PA monitors and the log sheet were returned to the research assistant. Any follow-up questions from the participants were addressed at this time.

ANALYSIS

SPSS version 23 (SPSS Inc. Chicago, IL) was utilized to analyze the results of this study. The variables that were assessed included total time in SB, total standing time, total stepping time, breaks in SB, steps per day, kcals, and active minutes. The change in each variable from week 1 to week 2 (both absolute change and %change) was computed separately for each group. Each of these measurements were compared for intervention group (vibration setting on during second week) and the control group (vibration setting off both weeks). Each of these variables were compared with independent-samples T-Tests. The statistical significance level was set at $\alpha < 0.05$.

Effect size was utilized to measure the meaningfulness of between-group differences in conjunction with significance levels.

CHAPTER IV

Journal Manuscript

ABSTRACT: The Effectiveness of Jawbone Monitors in Decreasing Sedentary Behavior in Adults.

BACKGROUND: Despite the overwhelming evidence that regular PA provides numerous health benefits and a preventative role in chronic disease, SB has been shown to be an independent risk factor for the development of chronic diseases. Currently, there are attempts to try to reduce population-based SB. Consumer-based PA monitors may have potential to help individuals reduce SB and increase PA. **PURPOSE:** This study aimed to determine if time spent in PA, SB, and number of breaks in SB was different if wearing the Jawbone UP24 and receiving haptic feedback compared to when no haptic feedback was provided. **METHODS:** Adult males (N=13) and females (N=13) wore the UP24 and activPAL monitor (criterion measure) over a two week period. For one week, the haptic feedback was turned off for all participants. For the second week, half of the participants had the haptic feedback activated so that the monitor would vibrate when the individual was sedentary ≥ 60 minutes. Differences in sitting time, standing time, stepping time, steps, upright events, and active minutes were compared between the control group and intervention group. **RESULTS:** The mean total times spent sitting, standing, stepping recorded by the activPAL accelerometer was non-significantly different, in the intervention group, with -25 minutes ($p=0.253$), +24 minutes ($p=0.160$), and +1.0 minute ($p=0.454$), respectively. The mean total steps were non-significantly different at +604 steps in the intervention group ($p=0.900$). The mean total upright events, were significantly higher by +9 upright events the intervention group ($p=0.030$). The mean total steps recorded by the Jawbone UP24 PA monitor were non-significantly

different at +796 steps in the intervention group ($p=0.412$). The mean total time spent during active time was non-significantly higher by +7 minutes in the intervention group ($p=0.057$).

CONCLUSIONS: This study showed statistically significant improvements in breaks in SB (upright events), as well as non-significant changes in the positive direction for other PA and SB variables. Haptic feedback from the UP24 monitor in the form of vibrations appeared to elicit short-term, positive behavioral modifications.

INTRODUCTION

It is recommended that adults accumulate 150 minutes per week of moderate-intensity physical activity (PA) or 75 minutes per week of vigorous-intensity PA in bouts of 10 minutes or more (69). These recommendations were put in place because participation in regular PA has been shown to play a role in the prevention of major chronic diseases such as cardiovascular disease, type II diabetes, obesity, and some types of cancer (6). Despite the overwhelming evidence that regular participation in moderate-intensity or vigorous-intensity PA (MVPA) provides numerous health benefits and a preventative role in chronic disease, SB has been shown to be an independent risk factor for the development of chronic diseases.

Sedentary behavior (SB) and the accumulation of SB have been shown to negatively influence health independently of PA and exercise participation (26). Health risks associated with SB include increased insulin resistance, increased fasting triglycerides, decreased daily caloric expenditures, and increased incidences of hypertension (53). Greer et al. found that men classified with middle (> 12 to < 19 hour/week) and high (> 19 hour/week) SB had 65-76% higher risk of developing metabolic syndrome independently of MVPA levels compared to individuals who were classified as having low level of SB (26). Moreover, Matthews et al. showed that the amount of time spent in SB was positively correlated with mortality after adjusting for covariates, such as age, weight, BMI, and gender (43, 44).

In addition to accumulated SB, the duration of bouts in SB has also been shown to increase health risks in addition to total accumulated SB. Cliff et al. found that children who spent longer time in bouts of SB had lower HDL cholesterol than those in shorter duration bout of SB (14). These findings were consistent with adult studies which indicate that limiting the duration of bouts of SB to < 30 minutes has beneficial effects on cardio-metabolic outcomes (57). Breaks in SB go

hand-in-hand with the duration of bouts spent in SB. Increased breaks in SB have been shown to decrease health risks involved with the accumulation of total SB. Breaks in SB have beneficial associations with waist circumference, body mass index, triglyceride levels, and 2-hour glucose levels that are independent of total SB and MVPA time (30). Dunstan et al. found that interrupting SB with short bouts of light- or moderate-intensity walking lowers postprandial glucose and insulin levels in overweight/obese adults (20). Therefore, current evidence suggests that breaking up SB may provide beneficial metabolic effects in addition to the beneficial effects of reducing total SB and increasing time spent in MVPA.

Recently, consumer-based PA monitors have become popular tools for individuals and researchers interested in tracking PA and SB. In 2014, an estimated 70.2 million consumer-based PA monitor devices were purchased in the U.S., Europe, and Asia (16). Over 500,000 Jawbone monitors were sold in the United States in 2014 and comprised roughly of 10% of the wearable activity tracker market in 2013 (1). The Jawbone UP monitor and other others such as the Apple Watch have settings that can cause vibrations when the wearer has been sedentary for too long. Vibration or haptic feedback is a type of prompting, which is a commonly used behavioral technique employed to elicit behavior change. Swartz et al. utilized two different prompting techniques (sound alerts and messages from a computer) to determine if haptic feedback could decrease SB (67). The standing group was asked to stand with no time constraint; whereas the stepping group was asked to walk 100 steps when prompted. Both intervention groups significantly reduced duration of average sitting bouts (Stand group, by 16%; Stepping group, by 19%) and the number of sitting bouts of 60 minutes or more (67). Despite this preliminary evidence that prompting may elicit behavior change, it is not known if consumer-based PA monitors utilizing haptic feedback are an effective tool for promoting higher PA levels and/or lower SB levels.

Therefore, the purpose of this study was to assess if wearing a Jawbone UP24 monitor which gives haptic feedback results in changes in SB.

METHODS

Participants

Participants for this study included 26 individuals who were either 1) members of Ball State University's Adult Physical Fitness Program 2) employees at Ball State University or 3) students at Ball State University in Muncie, Indiana. Participants 18-85 years of age were eligible to participate in this study. Individuals with an acute illness, any limiting orthopedic issues, or pregnant women were excluded from this study. Prior to participation, all participants gave written informed consent which was approved by Ball State University's Institutional Review Board.

Equipment

Study participants wore two PA monitors for a total duration of two weeks. A description of the equipment used follows.

Jawbone UP24 (AliphCom Inc., San Francisco, CA). The Jawbone is a wrist-worn, accelerometer-based PA monitor which tracks PA variables including energy expenditure (EE; Calories), steps, and active time (MVPA). The monitor has a rechargeable battery and synchronizes to a smartphone via Wi-Fi network and Jawbone application and can be downloaded via USB linking to a computer. The Jawbone's vibration feedback was used as the primary intervention tool in this study.

*activPAL Accelerometer*_(PAL Technologies Ltd) The activPAL is an accelerometer that is adhered to the participant's skin of the midline on the anterior aspect of the right thigh. The activPAL tracks standing time, sitting time, stepping time, steps, and upright events (breaks in

SB). The monitor has a rechargeable battery and can be downloaded via USB linking to a computer. The activPAL was initialized according to manufacturer instructions at the beginning of the first and third visits. The activPAL was used solely as a criterion measure of PA and SB in this study and not as part of the intervention strategy (18).

Protocol

Each participant reported to the Clinical Exercise Physiology Laboratory at Ball State University for each of the four visits. The initial visit to lab took place beginning on a Monday between 11:00 AM and 6:00 PM. The visit took approximately 30 minutes per participant. The initial visit to the lab began with an explanation and signing of the informed consent. Next, the researcher collected anthropometric characteristics of each participant which included height, weight, date of birth, and handedness via a scale, stadiometer, and a handedness questionnaire (49). Each participant was provided with an explanation on why the Jawbone UP24 may vibrate after a given period of time (i.e. if you are sedentary/inactive for ≥ 60 min there may be a vibration of the device). Participants were encouraged to stand up and move for a brief period of time (e.g., 1-2 minutes) if they felt a vibration from the Jawbone. No further information was disclosed on the health aspects associated with SB. For the first visit, the haptic feedback on the Jawbone monitors was disengaged for every participant for a baseline week of data collection.

Following the participant education/discussion portion the participants were then informed about the daily tracking involved with the use of a PA monitor. Each participant was provided with a PA log and was asked to record the day the monitor was worn, when the monitor was put on and taken off each day, and any exercise the participant participated in to determine if and for how long the monitor was taken off. Participants were instructed to remove the Jawbone for activities

such as showering, swimming, and water aerobics but were instructed to wear the monitors while sleeping. The activPAL was to be worn at all times.

Participant's sex, height, weight, and age were then entered by the research staff into the Jawbone UP24 application (on an iPod device). Finally, each participant was fitted with the activPAL accelerometer and Jawbone UP24 monitor by the research staff. activPAL placement was discussed earlier (middle portion of the anterior surface of the thigh) and the Jawbone monitor was placed on the participant's non-dominant wrist. Participants were then instructed to go about their normal lifestyle habits for one week.

The second visit took place one week after the initial visit, on a Monday between 7:00 AM to 11:00 AM. For the second visit, the research staff removed both PA monitors for charging and data collection and collected the PA log. Additionally, in half of the sample (intervention group) the haptic feedback was initialized on the Jawbone monitor to vibrate anytime between 8:00 AM to 10:00 when the participant was sedentary for ≥ 60 consecutive minutes. For the other half of the sample (control group) the haptic feedback was not initialized on the Jawbone monitor. The third visit was later the same day as the second visit, and participants were fitted with both PA monitors for an additional week of wear and given a second PA log. The fourth visit followed the third visit by one week, and for the fourth visit participants returned both PA monitors and the PA log. Also, the participant had an opportunity to ask any follow-up questions regarding the study. Contact information was verified so that the results of the study can be released to each participant if they so choose. Total wear time for the monitors included 12 full days and three partial days.

Data Analysis

In order for a participant's data to be included for analysis, both PA monitors had to be worn for ≥ 600 minutes/day on four days of both weeks/weekends of data collection. Non-wear time was assessed using the PA log, and data from the periods of the day in which the PA monitors were not worn were excluded from analysis. For the activPAL accelerometer, sleep time was not separated from SB. Therefore, the SB time output from the activPAL included both SB and sleep time since the monitors record sleep as SB.

activPAL variables (sitting time [SB], standing time, stepping time, steps, and upright events [breaks in SB]) were analyzed as change scores (week 2 - week 1) for each participant. Similarly, Jawbone UP24 activities (steps, calories, and active time) were analyzed as change scores. Change scores for all variables were compared between the control and intervention groups using independent samples t-tests. Additionally, effect sizes of the change scores were computed. Analyses were conducted using SPSS version 23 (IBM Inc., Armonk, NY) and Microsoft Excel (Microsoft Inc., Redmond, WA).

RESULTS

Descriptive characteristics of the participant population are displayed in Table 1. The majority of the sample (22 of the 26 participants) were right-hand dominant. All 26 participants had sufficient data collected by both PA monitors to be included in analyses. However, analyses were analyzed using sample sizes with the available data, which was not always the full sample size due to occasional errors in monitor synchronization. The average wear-time for the activPAL monitor was 1425.04 minutes (23.1 hours). However, due to limited participant feedback, average wear-time for the Jawbone monitor could not be determined. Synchronization errors with the

Jawbone monitors resulted in data loss for four participants for step counts and six participants for active minutes.

activPAL Results

activPAL Sitting: Figure 1 shows the mean total time spent sitting recorded by the activPAL accelerometer. The intervention group decreased sitting time by -23.0 ± 52.2 minutes in week 2 compared to week 1, and the control group increased sitting time by 1.9 ± 91.8 minutes; however despite -24.9 minutes change in sitting in the intervention group compared to the control group, these differences were not statistically significant ($p=0.406$). Table 3 shows a small effect size (0.33) for change in time spent sitting according to the activPAL. Additionally, 10/13 participants in the intervention group decreased sitting time in week 2 compared to week 1, whereas only 7/13 participants in the control group decreased sitting time.

activPAL Standing: Figure 1 shows the mean total time spent standing recorded by the activPAL accelerometer. The intervention group increased standing time by 4.1 ± 29.2 minutes in week 2 compared to week 1, and the control group decreased standing time by -19.8 ± 50.5 minutes; however despite +23.9 minutes change in standing in the intervention group, these differences were not statistically significant ($p=0.160$). Table 3 shows a moderate effect size (0.56) for change in time spent standing according to the activPAL. Additionally, 9/13 participants in the intervention group increased standing time in week 2 compared to week 1, whereas only 7/13 participants in the control group increased standing time.

activPAL Stepping: Figure 1 shows the mean total time spent stepping recorded by the activPAL accelerometer. The intervention group increased stepping time by 2.7 ± 25.6 minutes in week 2 compared to week 1 and the control group increased stepping time by 1.7 ± 35.6 minutes;

however despite +1.0 minute change in stepping in the intervention group, these differences were not statistically significant ($p=0.454$). Table 3 shows very small effect size (0.03) for change in time spent stepping according to the activPAL. Additionally, 10/13 participants in the intervention group increased stepping time in week 2 compared to week 1, whereas only 7/13 participants in the control group increased stepping time.

activPAL Steps: Figure 1 shows the mean total steps recorded by the activPAL accelerometer. The intervention group increased steps by 86 ± 1561 in week 2 compared to week 1 and the control group decreased steps by -517 ± 2583.0 ; however despite +603 steps change in steps taken in the intervention group, these differences were not statistically significant ($p=0.900$). Table 3 shows a moderate effect size (0.49) for change in time spent sitting according to the activPAL. Additionally, 8/13 participants in the intervention group increased steps in week 2 compared to week 1, whereas only 7/13 participants in the control group increased steps.

activPAL upright events: Table 2 shows the mean total upright events recorded by the activPAL accelerometer. The intervention group increased upright events by 7.55 ± 8.0 events per day in week 2 compared to week 1 and the control group decreased upright events by -1.5 ± 10.9 events, resulting in a significant mean difference of +9.1 upright events the intervention group compared to the control group ($p=0.030$). Table 3 shows a large effect size (0.87) for change in upright events according to the activPAL. Additionally, 10/13 participants in the intervention group increased upright events in week 2 compared to week 1, whereas 7/13 participants in the control group increased upright events.

Jawbone UP24 Results

Jawbone Steps: Figure 2 shows the mean total steps recorded by the Jawbone UP24 PA monitor. The intervention group increased steps by 351 ± 2139 in week 2 compared to week 1 and the control group decreased steps by -445 ± 2313 ; however despite +795.8 change in steps in the intervention group, these differences were not statistically significant ($p=0.412$). Table 3 shows a moderate effect size (0.53) for change in steps according to the Jawbone PA monitor. Additionally, 7/11 participants in the intervention group increased steps in week 2 compared to week 1, whereas only 6/11 participants in the control group increased steps.

Jawbone Active Minutes: Figure 2 shows the mean total time spent standing recorded by the activPAL accelerometer. The intervention group increased active minutes by 5.3 ± 7.2 minutes in week 2 compared to week 1 and the control group decreased active minutes by -1.5 ± 7.5 ; however despite +6.8 minutes change in active minutes in the intervention group, these differences were not statistically significant ($p=0.057$). Table 3 shows a large effect size (0.85) for change in active minutes according to the Jawbone PA monitor. Additionally, 8/11 participants in the intervention group increased active minutes in week 2 compared to week 1, whereas only 4/9 participants in the control group increased active minutes.

DISCUSSION

The aim of this study was to determine if wearing the Jawbone UP24 and receiving haptic feedback was related to changes in PA and SB. The findings of this study indicated that, in general, the Jawbone monitors did elicit statistically significant changes in behavior with regard to increased breaks in SB (upright events) shown from the activPAL. Several other variables also trended in the beneficial direction but the differences between the intervention and control groups

were not statistically significant, due in part to the small sample size. Effect sizes were utilized to measure the meaningfulness of between-group differences in conjunction with significance levels, which yielded meaningful (medium or high) effect sizes for several variables including standing time, number of steps taken, upright events (breaks in SB), and active minutes in studies using prompting or activity trackers for behavior change with moderate effect sizes in the activPAL standing and Jawbone steps taken data as well as high effect sizes in the activPAL upright events and Jawbone active minutes data (15). The results from this study were expected and are in agreement with previous research (Swartz and Wang) regarding decreased sitting time, increased breaks in SB, steps taken, and active minutes (67, 77). Swartz et al. found that prompts to disrupt sitting time significantly reduced total sitting time by 18.0 minutes, whereas this study showed a mean reduction of 23.0 minutes in the intervention group in the intervention week compared to baseline. Furthermore, Swartz et al. found that the number of sitting bouts of 60 minutes or more decreased by 54% (from 1.1 bout to 0.4 bouts) whereas this study found that the mean total of upright events taken significantly increased by 8 events per day in the intervention group (67). Similarly, Wang et al. found that wearable sensor/device prompts significantly increased steps per day by 1,266 and increased active time by 17.8 minutes per day in the intervention group which consisted of three text prompts throughout the day; the current study found that the non-significantly mean difference of change between the control group and the intervention group for steps taken was +795.8 steps/day and was +6.8 minutes/day for active minutes, according to the Jawbone monitor (77). These findings indicate that feedback in the form of prompts may be effective for eliciting short-term changes in both PA and SB, at least in some individuals.

A novel aspect of this study was that we were able to examine the effects of haptic feedback from a popular consumer-based PA monitor, rather than using prompts from other sources (e.g.,

computers, posted signs). Previous studies have primarily examined at the health risks associated with SB and how to reduce SB in regards to prompts (such as text message alerts) or standing desk stations or walking stations (35, 67). The prompts from Swartz et al. study included messages from the computer and alert sounds (beeps) from a PA monitor. Both of these prompts could be disruptive during the work-week and may not be as applicable as a silent vibration from a Jawbone or other consumer-based PA monitor. Additionally, the prompts in the Swartz et al. study were programmed to occur every 60 minutes regardless of behavior, whereas the Jawbone prompts did not occur unless the monitor recorded prolonged SB which may be less disruptive than prompts that occur consistently without regard to behavior. Additionally, prompts appear to be more effective when they occur in close proximity to the point where individuals perform the unwanted behavior, such as the vibration from the Jawbone when the individual is sedentary for too long. Prompts should also be obtrusive and thus noticeable to elicit behavioral modifications (3). Therefore, the behavior-specific prompts from the Jawbone are more likely to influence behavior than standard prompts that occur regardless of behavior according the significant upright events taken from the intervention group. Other intervention approaches, such as standing desk stations and/or treadmill walking stations can be expensive, whereas consumer-based PA monitors could be considered a low-burden intervention and are relatively inexpensive. Additionally, workstations are not portable, thereby restricting their prompting to only times when an individual is at his/her desk and does not take into account evenings and weekends in which individuals may spend large amounts of time in SB. Conversely, the Jawbone can provide prompts anywhere as long as the individual is wearing it, allowing for behavior tracking and prompting outside of work hours (e.g., evenings and weekends). Consumer-based PA monitors also require little assembly and no renovations to the office or home.

Prior to the current study, there has been little research done regarding to how well the haptic feedback from the PA monitors is at creating behavioral changes. However, there are studies that have shown how haptic feedback and prompting from other types of devices may promote behavioral adaptations (5, 48, 67). Swartz et al. utilized two different prompting techniques to determine if haptic feedback could decrease SB (67). The first prompt was in the form of an audible “beep” from a wrist-worn monitor that provided the feedback every hour. The second prompt utilized was an audible pop-up message on the computer screen every 60 minutes which said “Hello, please get out of your chair”. Each intervention group received both the wrist-worn feedback and the computer pop-up messages. However, the first intervention group was not given any directions on what to do when they received the feedback and the second intervention group was asked to walk 100 steps each time feedback was given. Both groups significantly reduced duration of average sitting bouts (Stand group, by 16%; Step group, by 19%) and the number of sitting bouts of 60 minutes or more (67). Therefore, there is evidence that devices that offer cues or prompts may cause a behavioral change. This aligns with the findings from the current study where participants did elicit behavior modifications (increased upright events) from the vibration prompt via the Jawbone UP24 PA monitor.

Furthermore, there are several psychological theories that exist that could potentially explain behavioral modifications in regards to prompts. Goal setting may be an effective strategy for improving PA and reducing SB (10, 64). Goal setting provides direction, determines the level of effort to be expended, fosters persistence, and supports the search for strategies. Psychologists have studied goal setting as a motivational technique looking at whether specific, difficult goals improves performances more than setting no goals. Researchers have also examined the relationship between various types of goals (i.e. specific or general, long-term or

short-term, difficult or easy) and PA with results indicating that goals both short and long-term were indeed associated with behavior changes (79). Overall, goal setting has been shown to be an excellent motivational tool to help positivity change PA behavior which may help inactive individuals adhere to long-term PA and reduction of SB. While the current study examined short-term effects of behavioral modification, there is evidence that goal setting (such as decreased SB via Jawbone UP24) may have positive behavioral modifications for individuals who utilize PA monitors. Also, the Stimulus-Response Theory (SRT) suggests an explanation of how people learn new behaviors. Although a behavior can be learned through repeated pairings of that behavior with antecedent cues or consequent reinforces, consequences have a greater impact on behavior than do antecedent cues (40). Punishment usually involves an unpleasant or uncomfortable stimulus after a behavior in order to decrease the probability of that behavior happening in the future (40). For the current study, the haptic feedback provided from the Jawbone UP24 monitor could be considered a punishment/consequence from spending too much time in SB. Therefore, the haptic feedback in the form of a vibration acted as a punishment of prolonged SB which may have elicited short-term behavioral modification in the experimental group in part due to the theory of the SRT.

In regards to the upright events category, the intervention group increased upright events by 7.6 ± 8.0 events per day in week 2 compared to week 1 and the control group decreased upright events by -1.5 ± 10.9 events, resulting in a significant mean difference of 9.1 upright events the intervention group. Given how little the sitting, stepping, and standing time changed in the intervention group in this study, it appears that the additional upright events that intervention participants took were mainly in the form of very short periods of standing. While not as beneficial to health as if these periods were higher-intensity PA, even standing breaks in SB have beneficial health effects (18). Stamatakis et al. found an independent beneficial effect of standing on

mortality (3 % decrease in risk per hour of standing), and this association was present in both those who met and did not meet the PA recommendations. Furthermore, Stamatakis' study suggests a dose-response relationship where replacing three hours of sitting per day with standing may be associated with a cumulative decrease of 12-18% in all-cause mortality risk (66). Ekblom-Bak et al. found that replacing SB with PA of any intensity and of as little as one minute were associated with significantly lower metabolic syndrome prevalence (23). The positive change in breaks in SB in our study provides support that a low-burden intervention such as wearing the Jawbone monitor and responding to prompts to break up SB may elicit favorable behavior adaptations that, in the long-term, could significantly reduce health risks (20).

While the protocol of this study utilized the Jawbone UP24 PA monitor to promote acute behavioral adaptations, the intent of this study was to understand the changes that may occur from receiving haptic feedback from any PA monitor or wearable technology. Several PA monitors on the market utilize haptic feedback to elicit behavioral modifications; examples include the Apple Watch, Fitbit Charge, and Garmin Vivosmart. Additionally, push notifications (vibrations or beeps) are ubiquitous in smartphone technology, and research supports that 'momentary assessment', or behavior-specific prompts, may encourage better adherence to medication use and other lifestyle habits (22). Together, these studies indicate the prompting in the form of haptic feedback from a PA monitor may encourage short-term behavior change.

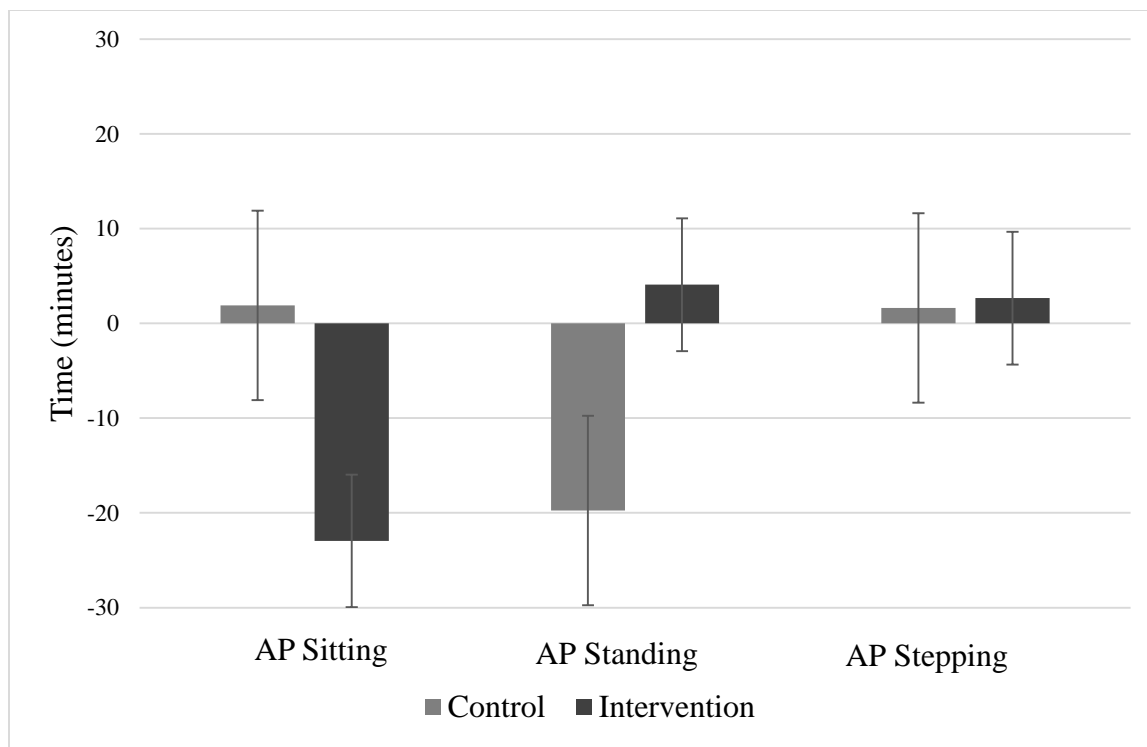
Despite positive short-term behavioral changes found in the current study and previous research, further research is needed to determine if these modifications continue long-term, with or without the continued use of a consumer-based PA monitor. Interestingly, the research staff in the current study received anecdotal evidence from several participants who reported that they had a better understanding of what it meant to be sedentary for an hour and that they could begin to

predict when the Jawbone would deliver its vibration. Such gains in awareness of behaviors are promising that suggests and suggests the participants may have been learning positive behavior adaptations even during a short intervention timeframe. This possibility should be explored more in future research.

The current study was not without limitations. Most notably, this study included sleep time while assessing the changes seen in total sitting time. The activPAL software records both sitting and lying down as “sitting time”, and the software is unable to differentiate between the two. Sleep is not considered SB, and if sleep time was captured and excluded from the data analysis, the results may have shown larger changes in total time spent in SB between groups. Sample size was also a study limitation, with only 26 participants (13 in each group). More participants would have given the results better generalizability, and the research team may have found more of the observed changes to be statistically significant with a larger sample. Finally, the research team only assessed behavioral adaptations over a two-week period, showing that behavioral adaptations are possible but not yielding data to assess the potential for long-term behavioral change.

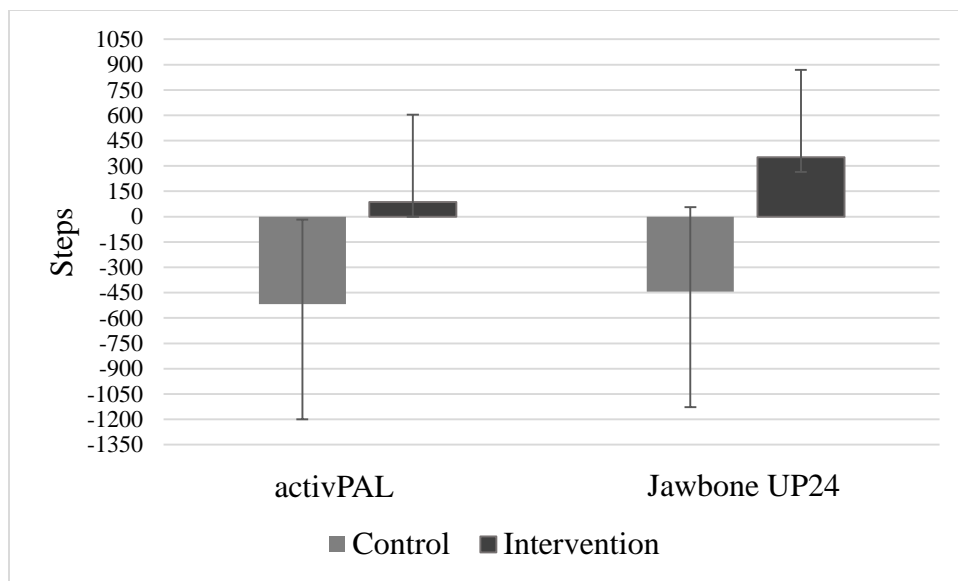
In conclusion, the current study showed significant improvements in breaks in SB, as well as non-significant improvements in other SB and PA variables for participants receiving behavior-specific prompts to encourage breaking up long periods of SB. This haptic feedback from the Jawbone UP24 monitor appears capable of eliciting short-term behavioral modifications. Consumer-based PA monitors and other devices offering haptic feedback may provide a convenient, low-cost intervention tool for the general population to alter PA and SB levels.

Figure 1. Mean differences between control group and intervention group for time (minutes) in sitting, standing, and stepping time.



Average mean differences between control and intervention groups.

Figure 2. Mean differences between the control group and intervention group for number of steps taken.



Average mean difference between control and intervention group.

Table 1. Participant descriptive characteristics.

	Total (N=26)	Control (N=13)	Intervention (N=13)
Age (yrs.)	43.9 ± 20.7	51.9 ± 22.4	35.8 ± 15.9
Height (in)	67.0 ± 3.6	66.4 ± 3.5	67.5 ± 3.8
Weight (kg)	76.1 ± 18.5	75.2 ± 16.7	77.0 ± 20.7
BMI (kg/m²)	26.0 ± 4.7	25.2 ± 6.1	26.9 ± 5.6

Values displayed as mean ± standard deviation (SD).

Table 2. Mean and SD of average upright events in the control group compared to the intervention group.

	Control	Intervention
Average events in week 1	59.1 ± 5.9	60.1 ± 5.4
Average events in week 2	57.6 ± 5.4	67.6 ± 4.1*

Values displayed as mean ± standard deviation (SD). * indicates mean is significantly different from control at $p < 0.05$.

Table 3. Effect size for each variable assessed in both the activPAL and Jawbone monitors.

	Effect Size
activPAL Sitting	0.33
activPAL Standing	0.56
activPAL Stepping	0.03
activPAL Steps	0.49
activPAL Upright Events	0.87
Jawbone Steps	0.53
Jawbone Active Minutes	0.85

Data are displayed as effect size.

CHAPTER V: Summary and Conclusions

This study addressed if wearing the Jawbone UP24 and receiving haptic feedback was related to positive changes in PA and SB compared to when the monitor was worn but no haptic feedback was provided. This was accomplished by assessing PA and SB in participants for two weeks with both the Jawbone UP24 monitor and the activPAL accelerometer during free-living conditions.

In brief summary, we hypothesized that wearing the Jawbone UP24 monitor and receiving haptic feedback would be related to decreased time spent in SB, time spent in bouts of SB, and increased breaks in SB. Furthermore, we hypothesized that wearing the Jawbone UP24 monitor and receiving haptic feedback would be related to increased number of steps taken, caloric expenditure, and active minutes.

Our major findings were that consumer-based PA monitors that provide haptic feedback, such as the Jawbone UP24, tended to elicit acute behavioral adaptations in the favorable direction (e.g., decreased SB, increased breaks in SB). The haptic feedback was related to increased breaks in SB by approximately nine times more per day in the intervention group from week 1 to week 2. Furthermore, the feedback increased the number of steps taken per day by 351 according to the Jawbone UP24 application in the intervention group. Finally, the haptic feedback increased standing time with a mean difference of change between weeks 1 of week 2 in the intervention group of 23.9 minutes. While only the change in breaks in SB was statistically significant, a large sample size likely would have resulted in significant differences in the other variables in the expected directions.

In conclusion, our findings indicate that consumer-based PA monitors that provide haptic feedback may help elicit acute behavioral adaptations. However, more research is needed to determine if these monitors can sustain behavioral change or if the consumers revert to old habits after the novelty of the feedback has dissipated. In addition to the haptic feedback provided from these monitors, consumer-based PA monitors also provide the user with important PA data such as number of steps take, EE, and active minutes in addition to other features such as tracking nutritional habits, goal settings, and physiological measurements such as heart rate. This real-time feedback was not evaluated in this study but may also help to elicit or sustain behavioral changes. In addition, the other variables measured in this study did not elicit significant changes hypothesized by the author. This could partially be explained by the small sampled size utilized for data collection, the differences in age groups in the control verses intervention group, and most notably; the inclusion of sleep time into total sitting time.

Recommendations for Future Study

Consumer-based PA monitors with haptic feedback should be further evaluated over longer duration periods. The current study consisted of two weeks of monitor wear time for each participant, with only one week of control and one week for the intervention in half of the individuals. Further research should look how these changes are similar, or different during a long-term intervention (e.g., 30-90+ days) to determine if the behavioral adaptations seen in this study are sustainable.

Although our study was primarily conducted in participants whom were already physically active, future research should determine if the effects seen from this study could be applied to individuals who are not physically active and spend large amounts of time in SB. It could by

hypothesized that individuals with higher SB and lower PA would see even greater behavioral adaptations than the current group of participants.

Due to time restraints, the current study was only able to utilize a sample size of 26 participants. Therefore, it was difficult to find statistically significant differences between the groups. Future studies should examine the effects of similar interventions in much larger cohorts. Finally, our study only examined the effects of the haptic feedback from one consumer-based PA monitor, the Jawbone UP24. While it may be assumed that similar feedback from other monitors would elicit the same behavioral adaptations, there should be further research on whether or not other devices (Apple Watch) find similar results. These future directions will assist our understanding of consumer-based PA monitors, both for researchers and individuals wishing to track various aspects of PA, SB, and health.

References

1. World Health Organization. Global Health Risks: Mortality and Burden of Disease Attributed to Selected Major Risks *World Health Organization* 2009.
2. **Aminian S, and Hinckson EA.** Examining the validity of the ActivPAL monitor in measuring posture and ambulatory movement in children. *Int J Behav Nutr Phys Act* 9: 119, 2012.
3. **Austin J, Hatfield DB, Grindle AC, and Bailey JS.** Increasing recycling in office environments: The effects of specific, informative cues. *J Appl Behav Anal* 26: 247-253, 1993.
4. **Bankoski A, Harris TB, McClain JJ, Brychta RJ, Caserotti P, Chen KY, Berrigan D, Troiano RP, and Koster A.** Sedentary activity associated with metabolic syndrome independent of physical activity. *Diabetes Care* 34: 497-503, 2011.
5. **Bellicha A, Kieusseian A, Fontvieille AM, Tataranni A, Charreire H, and Oppert JM.** Stair-use interventions in worksites and public settings - a systematic review of effectiveness and external validity. *Prev Med* 70: 3-13, 2015.
6. **Bennett GG, Wolin KY, Puleo EM, Masse LC, and Atienza AA.** Awareness of national physical activity recommendations for health promotion among US adults. *Med Sci Sports Exerc* 41: 1849-1855, 2009.
7. **Blair SN, Horton E, Leon AS, Lee IM, Drinkwater BL, Dishman RK, Mackey M, and Kienholz ML.** Physical activity, nutrition, and chronic disease. *Med Sci Sports Exerc* 28: 335-349, 1996.
8. **Booth FW, Laye MJ, and Roberts MD.** Lifetime sedentary living accelerates some aspects of secondary aging. *J Appl Physiol* (1985) 111: 1497-1504, 2011.
9. **Bravata DM, Smith-Spangler C, Sundaram V, Gienger AL, Lin N, Lewis R, Stave CD, Olkin I, and Sirard JR.** Using pedometers to increase physical activity and improve health: a systematic review. *JAMA* 298: 2296-2304, 2007.
10. **Buckworkth J DR.** Exercise Phsycoloogy *Champaign, IL: Human Kinetics* 2002.
11. **Byrne NM, Hills AP, Hunter GR, Weinsier RL, and Schutz Y.** Metabolic equivalent: one size does not fit all. *J Appl Physiol* (1985) 99: 1112-1119, 2005.
12. **Caspersen CJ, Powell KE, and Christenson GM.** Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep* 100: 126-131, 1985.
13. **Choi J, Lee JH, Vittinghoff E, and Fukuoka Y.** mHealth Physical Activity Intervention: A Randomized Pilot Study in Physically Inactive Pregnant Women. *Matern Child Health J* 2015.
14. **Cliff DP, Jones RA, Burrows TL, Morgan PJ, Collins CE, Baur LA, and Okely AD.** Volumes and bouts of sedentary behavior and physical activity: associations with cardiometabolic health in obese children. *Obesity (Silver Spring)* 22: E112-118, 2014.
15. **Cohen J.** *Statistical Power Analysis for the Behavioral Sciences* 1988.
16. **Dolan B.** Fitbit, Jawbone, Nike had 97 percent of fitness tracker retail sales in 2013. . National Purchas Diary Group 2013.
17. **Donaldson SC, Montoye AH, Tuttle MS, and Kaminsky LA.** Variability of Objectively Measured Sedentary Behavior. *Med Sci Sports Exerc* 48: 755-761, 2016.
18. **Dowd KP, Harrington DM, and Donnelly AE.** Criterion and concurrent validity of the activPAL professional physical activity monitor in adolescent females. *PLoS One* 7: e47633, 2012.
19. **Dunstan DW, Barr EL, Healy GN, Salmon J, Shaw JE, Balkau B, Magliano DJ, Cameron AJ, Zimmet PZ, and Owen N.** Television viewing time and mortality: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Circulation* 121: 384-391, 2010.
20. **Dunstan DW, Kingwell BA, Larsen R, Healy GN, Cerin E, Hamilton MT, Shaw JE, Bertovic DA, Zimmet PZ, Salmon J, and Owen N.** Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes Care* 35: 976-983, 2012.
21. **Dunstan DW, Salmon J, Healy GN, Shaw JE, Jolley D, Zimmet PZ, Owen N, and AusDiab Steering C.** Association of television viewing with fasting and 2-h postchallenge plasma glucose levels in adults without diagnosed diabetes. *Diabetes Care* 30: 516-522, 2007.

22. **Ehlers DK, Huberty J, Buman M, Hooker S, Todd M, and de Vreede GJ.** A Novel Inexpensive Use of Smartphone Technology for Ecological Momentary Assessment in Middle-Aged Women. *J Phys Act Health* 13: 262-268, 2016.
23. **Ekblom-Bak E, Ekblom O, Bergstrom G, and Borjesson M.** Isotemporal substitution of sedentary time by physical activity of different intensities and bout lengths, and its associations with metabolic risk. *Eur J Prev Cardiol* 2015.
24. **Ford ES, Li C, Zhao G, Pearson WS, Tsai J, and Churilla JR.** Sedentary behavior, physical activity, and concentrations of insulin among US adults. *Metabolism* 59: 1268-1275, 2010.
25. **Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP, and American College of Sports M.** American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc* 43: 1334-1359, 2011.
26. **Greer AE, Sui X, Maslow AL, Greer BK, and Blair SN.** The effects of sedentary behavior on metabolic syndrome independent of physical activity and cardiorespiratory fitness. *J Phys Act Health* 12: 68-73, 2015.
27. **Hamilton MT, Hamilton DG, and Zderic TW.** Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes* 56: 2655-2667, 2007.
28. **Hamilton MT, Healy GN, Dunstan DW, Zderic TW, and Owen N.** Too Little Exercise and Too Much Sitting: Inactivity Physiology and the Need for New Recommendations on Sedentary Behavior. *Curr Cardiovasc Risk Rep* 2: 292-298, 2008.
29. **Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A, American College of Sports M, and American Heart A.** Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation* 116: 1081-1093, 2007.
30. **Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, and Owen N.** Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care* 31: 661-666, 2008.
31. **Healy GN, Wijndaele K, Dunstan DW, Shaw JE, Salmon J, Zimmet PZ, and Owen N.** Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care* 31: 369-371, 2008.
32. **Hu FB, Li TY, Colditz GA, Willett WC, and Manson JE.** Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. *JAMA* 289: 1785-1791, 2003.
33. **Kampert JB, Blair SN, Barlow CE, and Kohl HW, 3rd.** Physical activity, physical fitness, and all-cause and cancer mortality: a prospective study of men and women. *Ann Epidemiol* 6: 452-457, 1996.
34. **Kang M, Marshall SJ, Barreira TV, and Lee JO.** Effect of pedometer-based physical activity interventions: a meta-analysis. *Res Q Exerc Sport* 80: 648-655, 2009.
35. **Katzmarzyk PT, Church TS, Craig CL, and Bouchard C.** Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Med Sci Sports Exerc* 41: 998-1005, 2009.
36. **Kosir S.** Wearables on the rise [Internet]. Consumer Electronics Association 2014.
37. **LaFontaine T, Dabney S, Brownson R, and Smith C.** The effect of physical activity on all cause mortality compared to cardiovascular mortality: a review of research and recommendations. *Mo Med* 91: 188-194, 1994.
38. **Larsen RN, Kingwell BA, Sethi P, Cerin E, Owen N, and Dunstan DW.** Breaking up prolonged sitting reduces resting blood pressure in overweight/obese adults. *Nutr Metab Cardiovasc Dis* 24: 976-982, 2014.
39. **Lloyd-Jones D, Adams R, Carnethon M, De Simone G, Ferguson TB, Flegal K, Ford E, Furie K, Go A, Greenlund K, Haase N, Hailpern S, Ho M, Howard V, Kissela B, Kittner S, Lackland D, Lisabeth L, Marelli A, McDermott M, Meigs J, Mozaffarian D, Nichol G, O'Donnell C, Roger V, Rosamond W, Sacco R, Sorlie P, Stafford R, Steinberger J, Thom T, Wasserthiel-Smoller S, Wong N, Wylie-Rosett J, Hong Y, American Heart Association Statistics C, and Stroke Statistics**

- S. Heart disease and stroke statistics--2009 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. *Circulation* 119: 480-486, 2009.
40. **Lox C.** Theories and Models of Exercise Behavior In: *The Psychology of Exercise* 2006, p. 62-85.
 41. **Lyons EJ, Lewis ZH, Mayrsohn BG, and Rowland JL.** Behavior change techniques implemented in electronic lifestyle activity monitors: a systematic content analysis. *J Med Internet Res* 16: e192, 2014.
 42. **Maki.** Increasing Therapeutic Exercise Participation by Individuals with Acquired Brain Injury using Self-Recording and Reinforcement *Behavioral Interventions* 23: 75-86, 2008.
 43. **Matthews CE, Chen KY, Freedson PS, Buchowski MS, Beech BM, Pate RR, and Troiano RP.** Amount of time spent in sedentary behaviors in the United States, 2003-2004. *Am J Epidemiol* 167: 875-881, 2008.
 44. **Matthews CE, George SM, Moore SC, Bowles HR, Blair A, Park Y, Troiano RP, Hollenbeck A, and Schatzkin A.** Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. *Am J Clin Nutr* 95: 437-445, 2012.
 45. **Miller NE, and Kraeling D.** Displacement: greater generalization of approach than avoidance in a generalized approach avoidance conflict. *J Exp Psychol* 43: 217-221, 1952.
 46. **Network SBR.** Standardized use of the terms “sedentary” and “sedentary behaviours”. *Appl Physiol Nutr Metab* 37: 540-542, 2012.
 47. **Nevels S.** Consumer interest in purchasing wearable fitness devices [Internet] Consumer Electronics Association 2014.
 48. **O'Neil.** Supporting Sit-to-Stand Rehabilitation Using Smartphone Sensors and Arduina Haptic Feedback Modules 2015.
 49. **Oldfield RC.** The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia* 9: 97-113, 1971.
 50. **Oliver M, Schluter PJ, Healy GN, Tautolo el S, Schofield G, and Rush E.** Associations between breaks in sedentary time and body size in Pacific mothers and their children: findings from the Pacific Islands Families study. *J Phys Act Health* 10: 1166-1174, 2013.
 51. **Owen N, Bauman A, and Brown W.** Too much sitting: a novel and important predictor of chronic disease risk? *Br J Sports Med* 43: 81-83, 2009.
 52. **Owen N, Healy GN, Matthews CE, and Dunstan DW.** Too much sitting: the population health science of sedentary behavior. *Exerc Sport Sci Rev* 38: 105-113, 2010.
 53. **Owen N, Sparling PB, Healy GN, Dunstan DW, and Matthews CE.** Sedentary behavior: emerging evidence for a new health risk. *Mayo Clin Proc* 85: 1138-1141, 2010.
 54. **Paffenbarger RS, Jr., Blair SN, and Lee IM.** A history of physical activity, cardiovascular health and longevity: the scientific contributions of Jeremy N Morris, DSc, DPH, FRCP. *Int J Epidemiol* 30: 1184-1192, 2001.
 55. **Paffenbarger RS, Jr., and Lee IM.** Intensity of physical activity related to incidence of hypertension and all-cause mortality: an epidemiological view. *Blood Press Monit* 2: 115-123, 1997.
 56. **Pate RR.** Physical activity and health: dose-response issues. *Res Q Exerc Sport* 66: 313-317, 1995.
 57. **Peddie MC, Bone JL, Rehrer NJ, Skeaff CM, Gray AR, and Perry TL.** Breaking prolonged sitting reduces postprandial glycemia in healthy, normal-weight adults: a randomized crossover trial. *Am J Clin Nutr* 98: 358-366, 2013.
 58. **Powell KE, Paluch AE, and Blair SN.** Physical activity for health: What kind? How much? How intense? On top of what? *Annu Rev Public Health* 32: 349-365, 2011.
 59. **Reiner M, Niermann C, Jekauc D, and Woll A.** Long-term health benefits of physical activity--a systematic review of longitudinal studies. *BMC Public Health* 13: 813, 2013.
 60. **RM R.** Facilitating health behaviour change and its mainenance: Interventions based on Self-Determination Theory *The European Health Psychologist* 10: 2008.

61. **Ryan.** Sitting patterns at work: objective measurement of adherence to current recommendations. *Ergonomics* 2011.
62. **Schulte MF.** Few facts from the Centers for Disease Control and Prevention. *Front Health Serv Manage* 25: 1-2, 2008.
63. **Services. USDoHaH.** Physical Activity and Health: A report of the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, CDC, National Center for Chronic Disease Prevention and Health Promotion. 1996 1278p. .
64. **Solley E.** Improving Consistency of Goal Attainment to Increase Physical Activity *University of South Florida* 2014.
65. **Stamatakis E, Hamer M, and Dunstan DW.** Screen-based entertainment time, all-cause mortality, and cardiovascular events: population-based study with ongoing mortality and hospital events follow-up. *J Am Coll Cardiol* 57: 292-299, 2011.
66. **Stamatakis E, Rogers K, Ding D, Berrigan D, Chau J, Hamer M, and Bauman A.** All-cause mortality effects of replacing sedentary time with physical activity and sleeping using an isotemporal substitution model: a prospective study of 201,129 mid-aged and older adults. *Int J Behav Nutr Phys Act* 12: 121, 2015.
67. **Swartz AM, Rote AE, Welch WA, Maeda H, Hart TL, Cho YI, and Strath SJ.** Prompts to disrupt sitting time and increase physical activity at work, 2011-2012. *Prev Chronic Dis* 11: E73, 2014.
68. **Thomas JG, and Bond DS.** Behavioral response to a just-in-time adaptive intervention (JITAI) to reduce sedentary behavior in obese adults: Implications for JITAI optimization. *Health Psychol* 34 Suppl: 1261-1267, 2015.
69. **Thompson PD, Arena R, Riebe D, Pescatello LS, and American College of Sports M.** ACSM's new preparticipation health screening recommendations from ACSM's guidelines for exercise testing and prescription, ninth edition. *Curr Sports Med Rep* 12: 215-217, 2013.
70. **Thorp AA, Healy GN, Owen N, Salmon J, Ball K, Shaw JE, Zimmet PZ, and Dunstan DW.** Deleterious associations of sitting time and television viewing time with cardiometabolic risk biomarkers: Australian Diabetes, Obesity and Lifestyle (AusDiab) study 2004-2005. *Diabetes Care* 33: 327-334, 2010.
71. **Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, and McDowell M.** Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* 40: 181-188, 2008.
72. **Trost SG, McIver KL, and Pate RR.** Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sports Exerc* 37: S531-543, 2005.
73. **Tudor-Locke C.** Taking Steps toward Increased Physical Activity: Using Pedometers to Measure and Motivate *President's Council on Physical Fitness and Sports Research Digest* 2002.
74. **Tudor-Locke C, and Bassett DR, Jr.** How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Med* 34: 1-8, 2004.
75. **Tudor-Locke C, and Lutes L.** Why do pedometers work?: a reflection upon the factors related to successfully increasing physical activity. *Sports Med* 39: 981-993, 2009.
76. **U.S.** 2008 Physical Activity Guidelines for Americans. .
77. **Wang JB, Cadmus-Bertram LA, Natarajan L, White MM, Madanat H, Nichols JF, Ayala GX, and Pierce JP.** Wearable Sensor/Device (Fitbit One) and SMS Text-Messaging Prompts to Increase Physical Activity in Overweight and Obese Adults: A Randomized Controlled Trial. *Telemed J E Health* 21: 782-792, 2015.
78. **Ward DS, Evenson KR, Vaughn A, Rodgers AB, and Troiano RP.** Accelerometer use in physical activity: best practices and research recommendations. *Med Sci Sports Exerc* 37: S582-588, 2005.
79. **Weinberg R.** Foundation of sport and exercise psychology 3rd edition. . *Champaign, IL: Human Kinetics* 329-349, 2003.
80. **Welk G.** Physical Activity Assessment for Health-Related Research. *Circulation* 261, 2002.
81. **Whaley MH, and Blair SN.** Epidemiology of physical activity, physical fitness and coronary heart disease. *J Cardiovasc Risk* 2: 289-295, 1995.

APPENDIX A

Photographs



NAME: _____

Ball State University
Clinical Exercise Physiology Program
Physical Activity Monitor Instructions & Log Form

- The Jawbone UP24 monitor will be placed on your non-dominant wrist during your visit to the Human Performance Laboratory. Please remove the monitor during activities that include water, and then slide the activity monitor back onto your non-dominant wrist after you are dry. (Not back side for description and pictures).
- Please do your normal activities while wearing the PA monitor.
- The PA monitor should be worn at all times except when swimming, showering, or sleeping. You do not need to do anything to the PA monitor (like pushing a button), just wear it.
- If you have questions please call the lead student investigator, Joshua Board, at 737-235-5062.
- Record responses to each of the items below for each day you wear the PA monitor. If you answer "yes" to a question, please write down a description of the time removed/exercise bout in the lines below the table.
- We ask that you wear the PA monitor for 6 consecutive days.
- Bring this log form with you when you return the PA monitor to Joshua Board in the Human Performance Laboratory.

Monitor # _____ Day starting monitor wear _____ Return date and time _____

Date (ex. 9/15/15)	Removed or left off for part of the day?	Performed a bout of exercise?	Time wake up	Time monitor was taken off for any reason	Time monitor was put back on	Time went to bed
/ /	YES NO	YES NO	AM	AM	PM	PM
/ /	YES NO	YES NO	AM	AM	PM	PM
/ /	YES NO	YES NO	AM	AM	PM	PM
/ /	YES NO	YES NO	AM	AM	PM	PM
/ /	YES NO	YES NO	AM	AM	PM	PM
/ /	YES NO	YES NO	AM	AM	PM	PM
/ /	YES NO	YES NO	AM	AM	PM	PM
/ /	YES NO	YES NO	AM	AM	PM	PM
/ /	YES NO	YES NO	AM	AM	PM	PM

For any items circled YES, please list the date and an explanation (using final space below and on the back of this sheet)
For example: 5/26 - forgot to wear monitor, from 1:00-3:00pm,
5/27 - walked on the Cardinal Greenway for 60 minutes, from 10:30-11:30am.

Continued on back